High-Performance Nanostructured Materials

Multilayer materials have extensive technological potential

Nanostructure or nanophase materials are dense, ultrafine-grained, high-interface-concentration solids, characterized by microscopic microstructures and thus by large interfacial area-to-volume ratios.

To date, most nanostructured materials have been synthesized by the inert or reactive gas "smoke" process for nanoparticle synthesis, and exhibit attractive sintering behaviors, minimal interface contamination, and average grain sizes of 5 to 10 nm.

Multilayers can be synthesized from any element using molecular beam epitaxy, evaporation, sputtering, physical vapor deposition, and electrochemical atom-by-atom technologies. The microstructural scale of multilayer materials is typically determined during synthesis by controlling the thickness of individual layers. Layers are one monolayer (0.2 nm) to hundreds of monolayers (>500 nm) thick and, except in special cases, generally define the in-depth grain size. Until now, the macroscopic thickness of nanostructure multilayer materials has been limited to less than 1 μm.

New methodology for synthesis

We have developed processes for magnetron sputter deposition of thick macroscopic, nanostructure multilayer materials that we use to fabricate free-standing, high-quality structures up to 0.5-mm thick containing up to 50,000 individual layers. Our synthesis system produces samples that have periods uniform to 5% of the individual layer thickness and areas of approximately 700 cm^2, which enables application of standard techniques for property determination, facilitates traditional characterization approaches, and will foster new, powerful solutions to demanding technological needs.

APPLICATIONS

- *High-performance coatings*
- *High-performance capacitors*
- *Integrated circuit interconnects*
- *Magneto-optic read/write memory and magnetic transducers*
- *X-ray optics and high-performance visible optics*

The tensile strength of this 70-mm-thick copper–zirconium multilayer structure is 115 GPa (about 5 times that of copper), with a ductility greater than 15%.

Because of their microstructures and atomic distributions, these macroscopic materials have the potential for exceptional mechanical performance. Also, mechanically active flaws that often limit performance are controllable, allowing us to fully develop the potential offered by structural control during multilayer synthesis.

Research and technological uses

The research and technological potential of these materials is extensive because of the levels of structural and compositional control possible. Multilayer technology will become an important advanced materials technology in the next decade—when multilayer fabrication becomes economically competitive with other high-volume synthesis and processing technologies.

Availability: The technology is available now. We seek industrial partners with whom we can explore commercial applications and prototype materials.

Contact

Troy Barbee
Phone: (510) 423-7796
Fax: (510) 422-6892
E-mail: barbee2@llnl.gov
Mail code: L-350